THE RADIATION ENVIRONMENT INSIDE EGO AND POGO

by

J. W. Lindner
T. A. Farley

OGO PROGRAM OFFICE

8100.2-73

20 April 1961

Prepared for
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Under Letter Contract NAS5-899

SPACE TECHNOLOGY LABORATORIES, INC.
P. O. Box 95001
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INTEROFFICE CORRESPONDENCE

8100.2-74

TO: Distribution

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DATE: 21 April 1961

SUBJECT: The Radiation Environment Inside EGO and POGO

FROM: J. W. Lindner

A previous memorandum (8100.2-73, The Radiation Environment of EGO and POGO - J. W. Lindner and T. A. Farley - April 20, 1961) described the radiation environment over the orbit of the EGO and POGO satellites. The purpose of this memorandum is to use the data from the previous memorandum to calculate the radiation dosage received by components in the interior of these spacecraft.

The exact calculation of the dosage at a particular point inside the spacecraft is an extremely difficult task since it is necessary to take account of absorption effects, scattering, production of secondary radiation (bremsstrahlung X-rays), and shadowing of a point by an array of irregularly shaped boxes. However, it is felt that such an exact calculation is not really necessary or even justified in this case. The initial data is uncertain by as much as one or two orders of magnitude. In addition, only the order of magnitude of the intensity is required to evaluate most of the radiation effects.

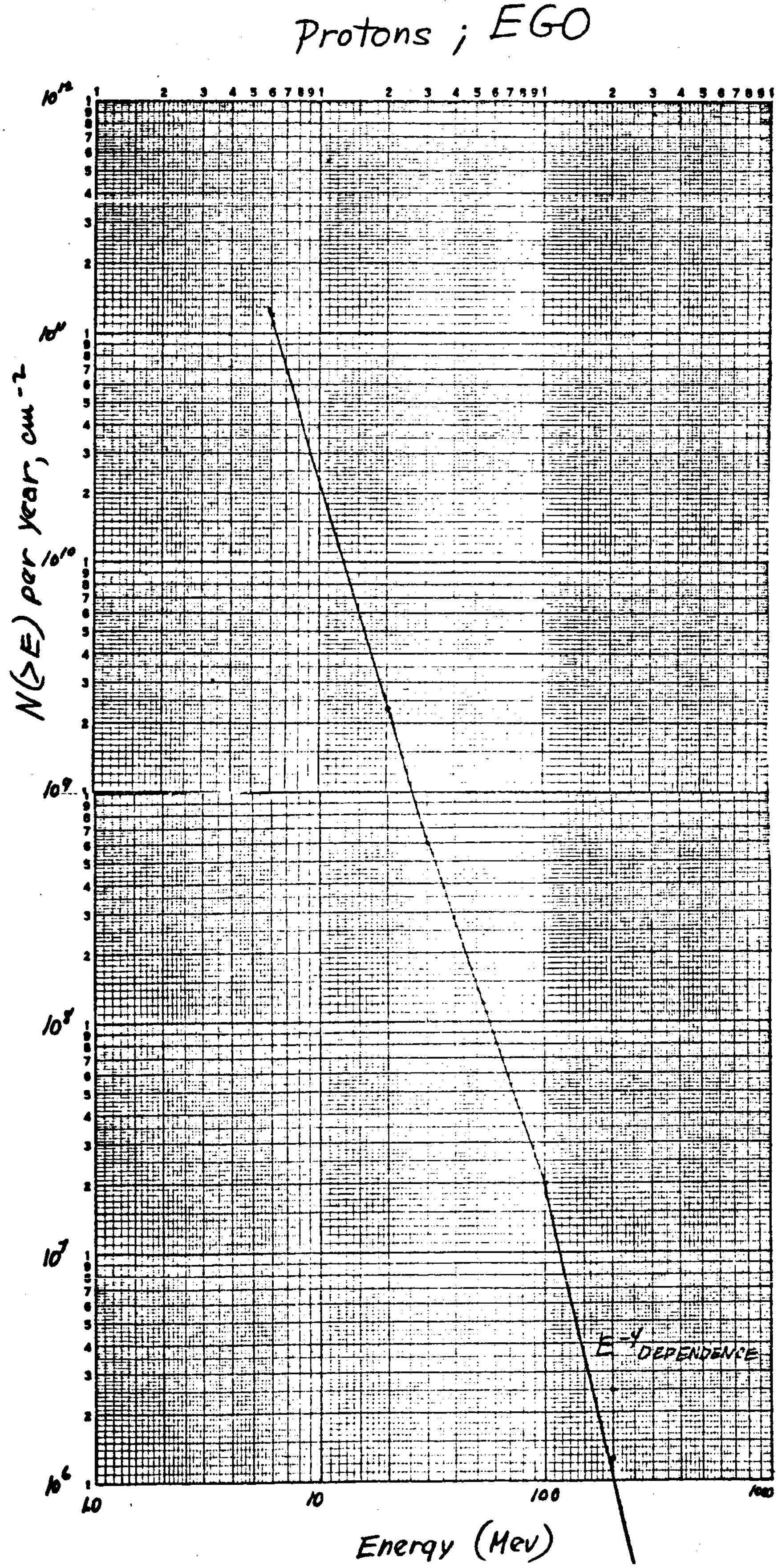
The calculations carried out in this memorandum give the radiation dosage as a function of shield thickness. The shield thickness should be considered to be the minimum mass of material between a particular component and the outside of the spacecraft. The calculations have been carried out for an aluminum shield. Most light elements ($Z < 30$) may be considered equivalent to aluminum - that is the same mass thickness (gm/cm^2) of any light element will provide the same amount of shielding. Heavier elements are somewhat more effective, but not by much more than a factor of two.

Damage thresholds of most materials are usually tabulated in terms of total energy absorption within the material. The most commonly used units are ergs/gm and Roentgen (R). A convenient conversion factor between these units is 1 R = 100 ergs/gm.

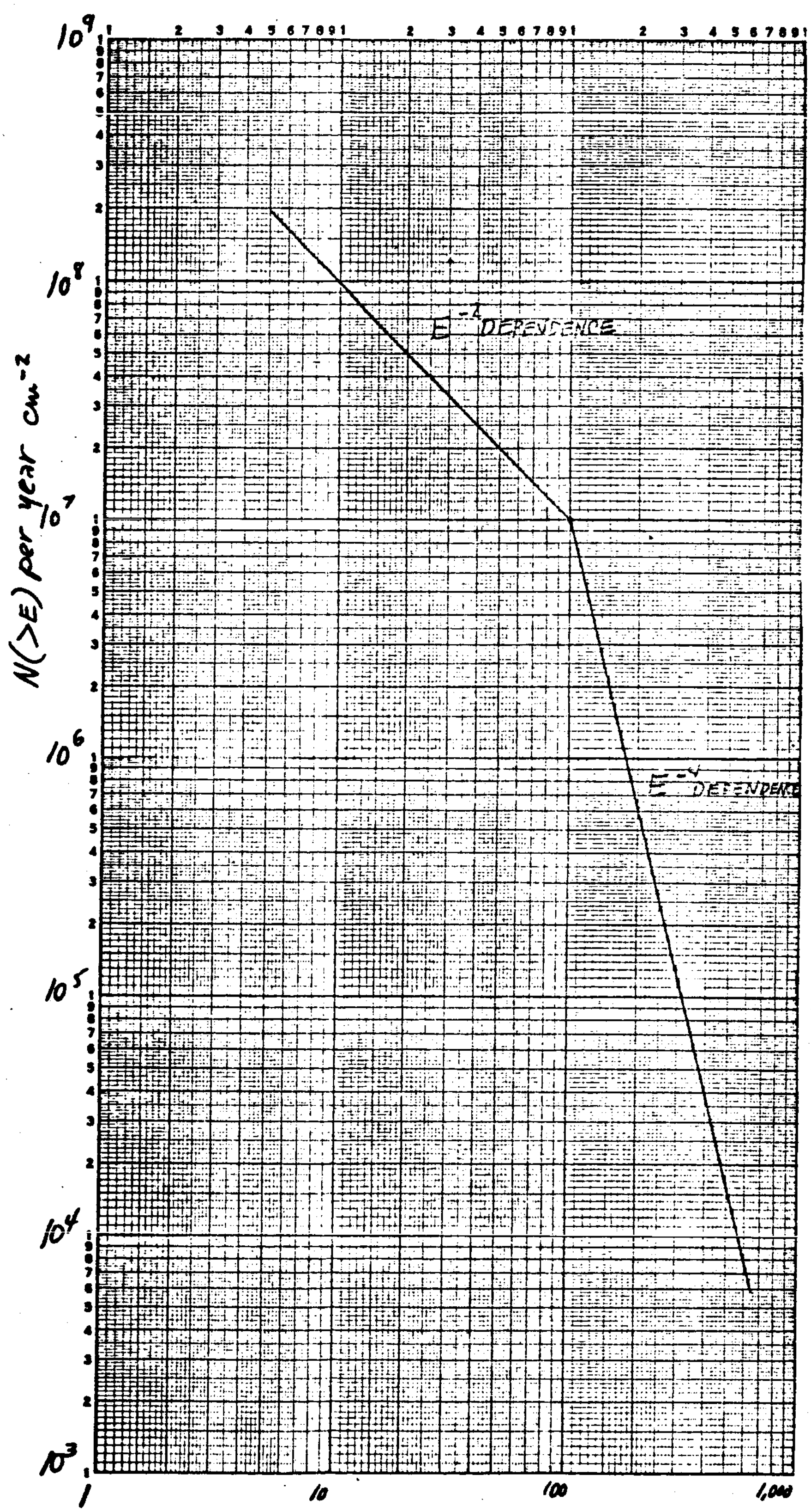
Other terms often used are REM (Roentgen equivalent mass), REP (Roentgen equivalent physical), and RAD. For OGO design purposes, these units may all be taken as equivalent to Roentgen.

A. PROTONS

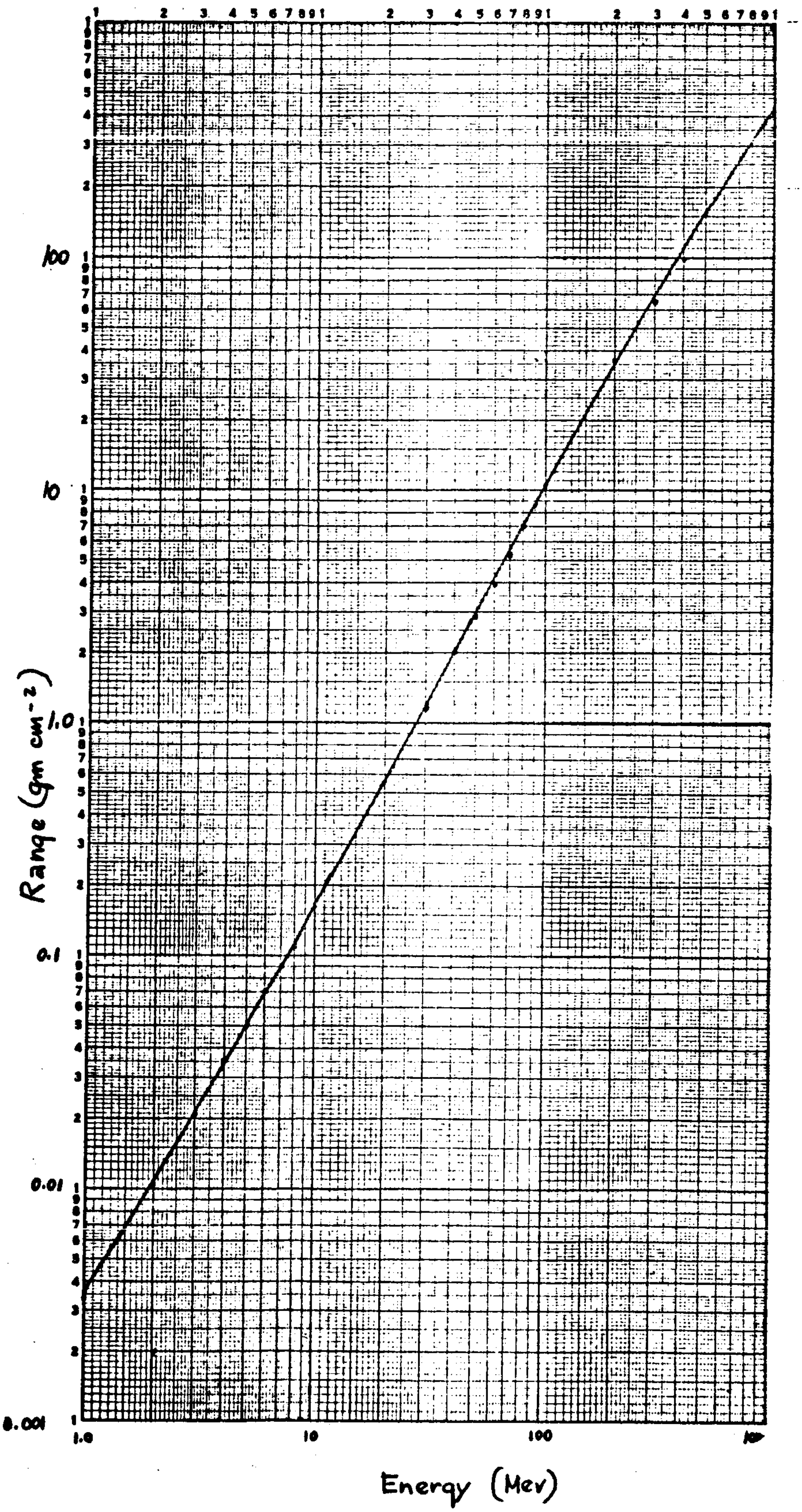
The total flux of protons as a function of energy upon the EGO and POGO spacecraft is plotted in Figures 1 and 2 respectively. These curves plot the integral proton flux - that is the total number of protons with energy greater than E - as a function of energy. The range of protons in aluminum is plotted in Figure 3.


Protons ; EGO
$N(\geq E)$ per year, cm^{-2}
10^{12}
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
1.0
10
100
1000
Energy (Mev)
E^{-4} DEPENDENCE

Protons POGO



Protons ; Range vs Energy (in Al)



To within about a factor of 4, a flux of 10^6 protons/cm^2 will produce a dose of 1 Roentgen in most materials. Using this approximation, the total annual dose from protons as a function of shield thickness is given in Table 1. Due to the uncertainty in the total flux (especially for low energies), these results are probably only accurate to an order of magnitude.

TABLE I

Shield Thickness		Total Annual Dose (R/yr)-Protons	
gm/cm^2	In. Al*	EGO	POGO
0	0	$>10^5$	$>10^2$
.068	.010	10^5	10^2
.340	.050	6×10^3	$<10^2$
.680	.100	10^3	$<10^2$
1.020	.150	$<10^3$	$<10^2$
1.360	.200	$<10^3$	$<10^2$
1.700	.250	$<10^3$	$<10^2$

Density of Aluminum = 2.7 gm/cc = 168 lb/ft^3

B. ABSORPTION OF ELECTRONS

Electrons will lose energy by two processes: ionization and radiation (bremsstrahlung). The exact calculation of the radiation dosage under a shield irradiated with electrons of various energies is a very complicated problem. However, since there is an uncertainty of one to two orders of magnitude in the incident flux, it is reasonable to use approximate calculations. The two processes will be treated independently although they are very much related. This treatment is only valid since most of the electrons have energy less than 200 kev.

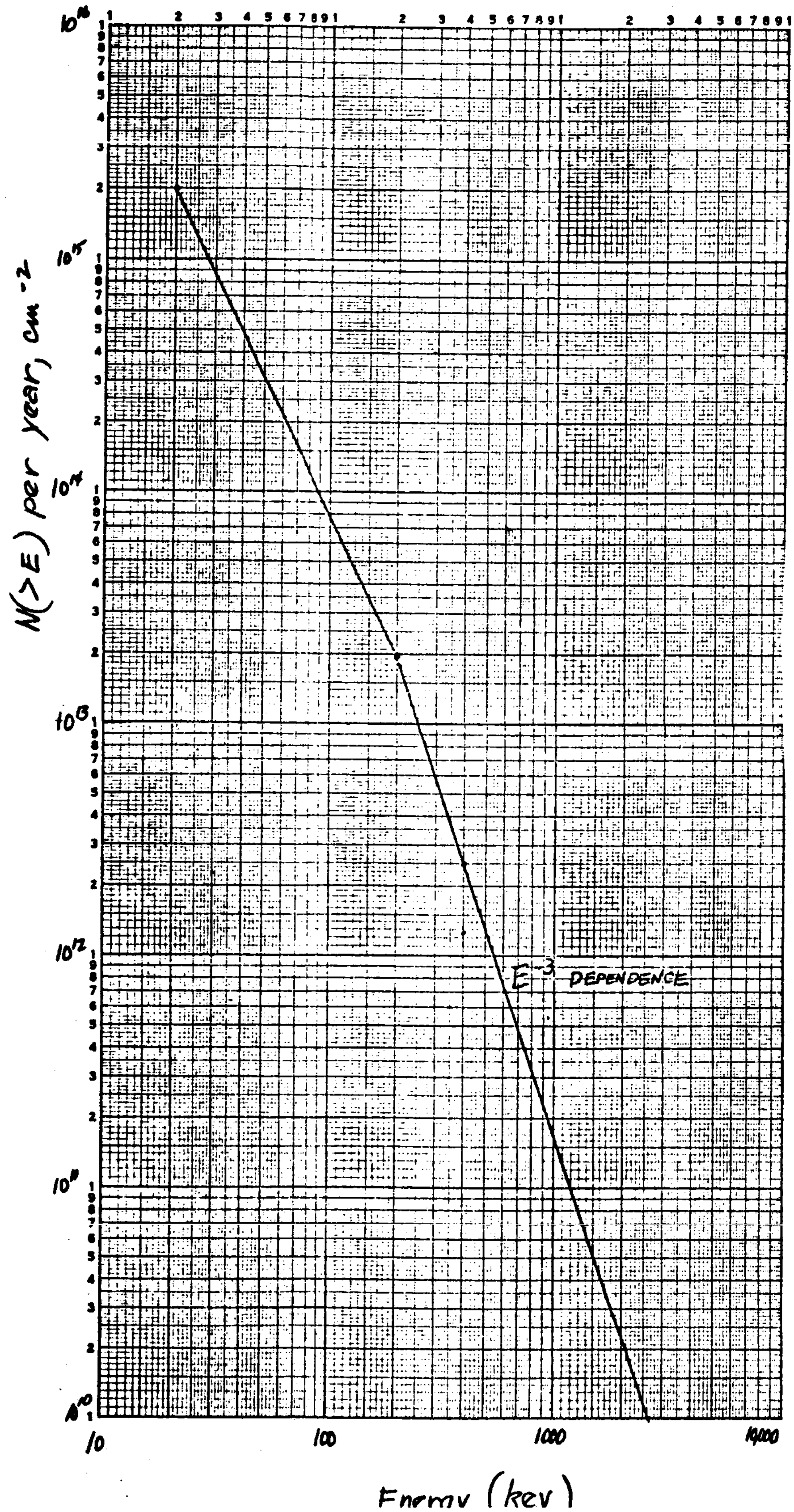
Figure 4 is a plot of the range of electrons in aluminum as a function of energy. This curve is valid for all light elements ($Z < 30$). Figure 5 and 6 are plots of the calculated annual electron flux for EGO and POGO.

Over the energy range of interest, approximately 1.5 to 3×10^7 electrons/cm^2 will cause a dose of 1 Roentgen. Using this relationship and neglecting scattering, shielding by other units within the spacecraft, and radiation, the total annual dose from electrons as a function of shield thickness is tabulated in Table 2.

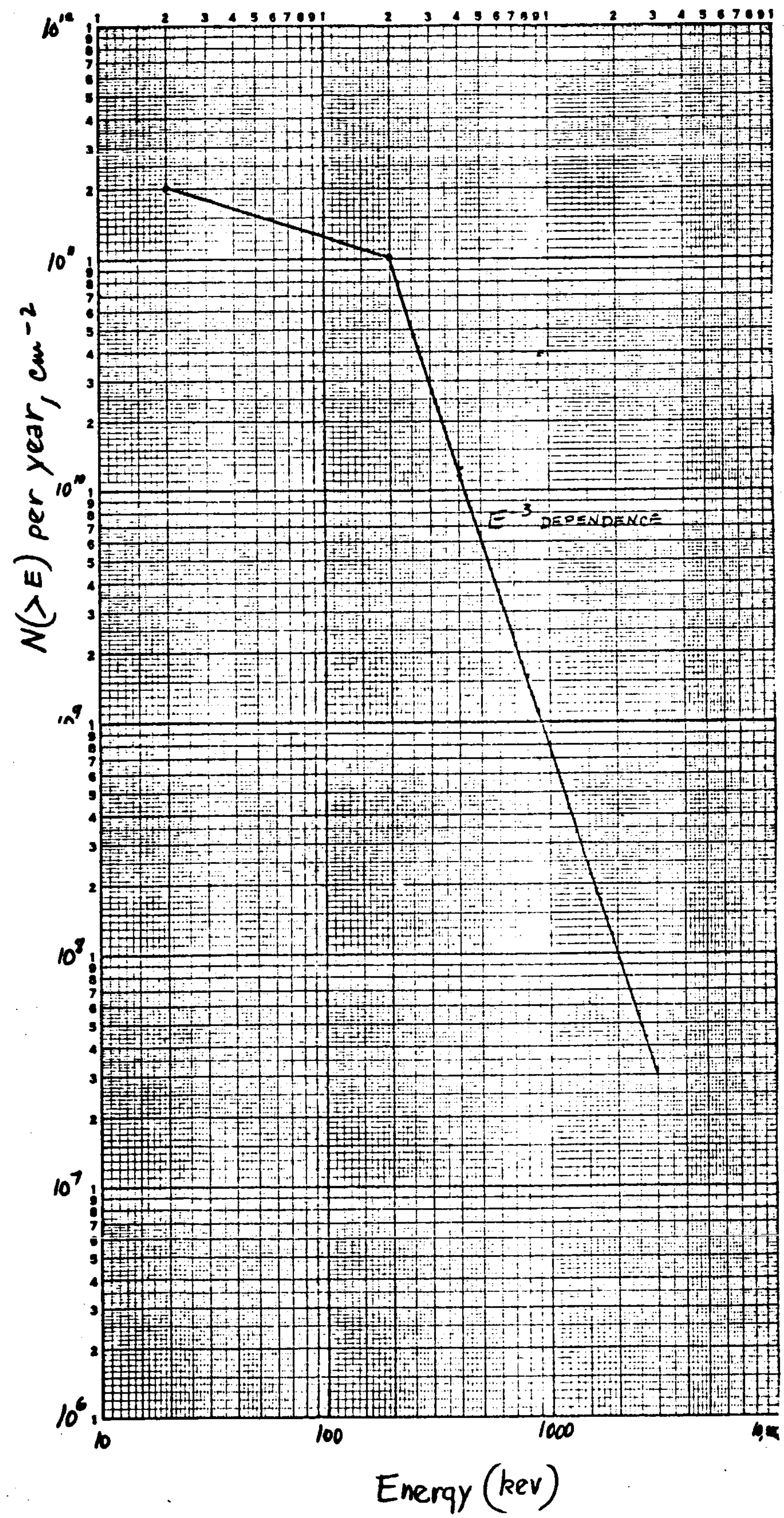
TABLE 2

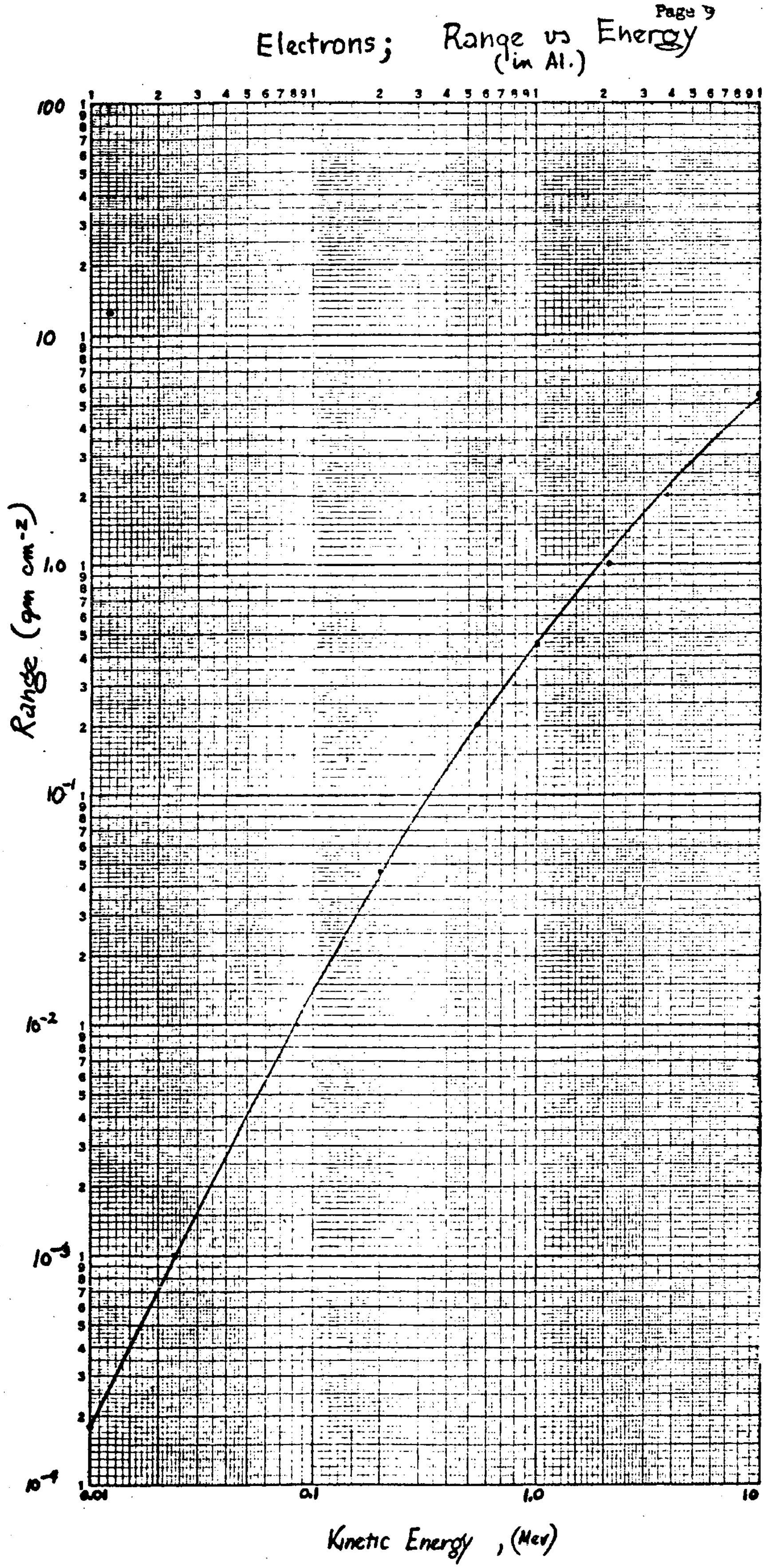
Shield Thickness		Total Annual Dose (R/yr)-Electrons	
gm/cm^2	In. Al	EGO	POGO
0	0	10^8	10^5
.068	.010	5×10^5	3×10^4
.340	.050	2×10^4	$<10^3$
.680	.100	2×10^3	$<10^3$
1.020	.150	10^3	$<10^3$
1.360	.200	$<10^3$	$<10^3$
1.700	.250	$<10^3$	$<10^3$

Electrons , EGO



Electrons ; POGO




Electrons; Range vs Energy
(in Al.)
100
10
1.0
10^-1
10^-2
10^-3
10^-4
Range (gm cm^-2)
0.01
0.1
1.0
10
Kinetic Energy, (Mev)

C. SECONDARY X-RAYS

For the electron energies expected to be encountered in the EGO and POGO missives, approximately 0.1 percent of the electron energy will be converted into X-rays. This conversion process occurs throughout the range of the electrons. For the purpose of this calculation, it has been assumed that the complete conversion occurs at a depth of .068 gm/cm^2 of aluminum (.010 in.) and that the average energy of the radiation is 75 kev. The energy figure is deliberately chosen to be higher than the average energy of the electrons to correct for scattering and X-Ray production deeper in the shield. The total annual dose from secondary X-rays is approximately 10^3 R/yr nearly everywhere inside the EGO spacecraft and is less than 1 R/yr inside POGO.

The total annual radiation dose for components inside the EGO and POGO spacecraft from all sources is tabulated in Table 3. The uncertainty on all numbers should be taken as plus or minus a factor of ten for design purposes.

TABLE 3

Shield Thickness		Total Annual Dose (R/yr)-All Sources	
gm/cm^2	In. Al	EGO	POGO
0	0	10^8	10^5
.068	.010	6×10^5	3×10^4
.340	.050	3×10^4	10^3
.680	.100	4×10^3	$< 10^3$
1.020	.150	2×10^3	$< 10^3$
1.360	.200	10^3	$< 10^3$
1.700	.250	10^3	$< 10^3$

D. CONCLUSIONS

The data presented in Table 3 may be used to estimate the possible radiation damage to components other than transistors and solar cells. The following conclusions may be made:

1. The only questionable material for use within the spacecraft is TEFLON. The integrated annual dose in the EGO spacecraft may be sufficient to

cause measurable damage. If its use cannot be avoided in a particular component, it is suggested that damage tests be carried out on that component to determine if the radiation damage will significantly degrade its operation in the function it will perform within the spacecraft.

2. It is suggested that the data presented in a previous memorandum (8100.2-58 - Materials for Use in the Radiation Environment of OGO - J. W. Lindner - March 30, 1961) be used to choose electrical components for use on the outside of the spacecraft (e.g. wiring to boom experiments, connectors, etc.).

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JWL:cpr